PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F16K 31/02 | A1

(11) International Publication Number: WO 97/17561

(43) International Publication Date: 15 May 1997 (15.05.97)

(21) International Application Number: PCT/US95/14827

(22) International Filing Date: 9 November 1995 (09.11.95)

(30) Priority Data:
08/358,331 9 November 1994 (09.11.94) US

(71) Applicant: AURA SYSTEMS, INC. [US/US]; 2335 Alaska Avenue, El Segundo, CA 90245 (US).

(72) Inventors: MORINIGO, Fernando, B.; 8837 Glider Avenue, Los Angeles, CA 90045 (US). GOLDSTEIN, Carmi; 1188 Casiano Road, Los Angeles, CA 90049 (US). BULGATZ, Dennis; 6522 Yarmouth Avenue, Reseda, CA 91355 (US).

(74) Agent: MERKADEAU, Lisa, A.; Aura Systems, Inc., 2335 Alaska Avenue, El Segundo, CA 90245 (US).

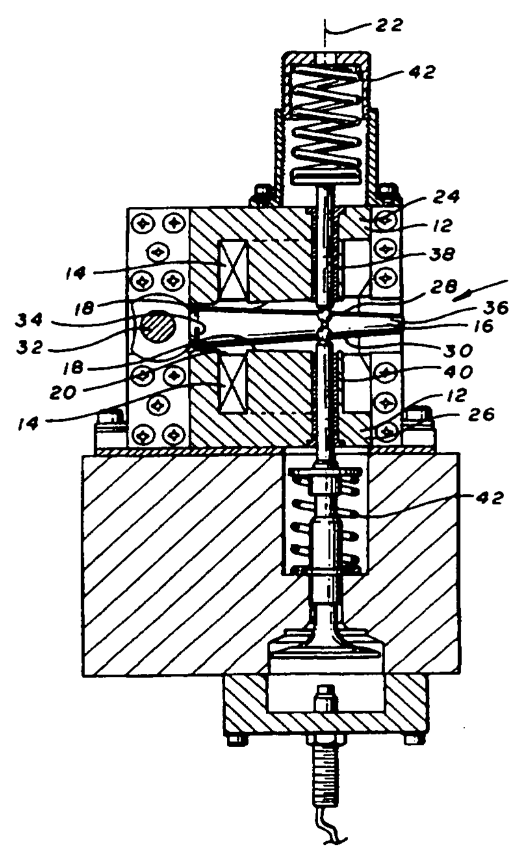
(81) Designated States: AU, CA, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: HINGED ARMATURE ELECTROMAGNETICALLY ACTUATED VALVE

(57) Abstract

An electromagnetically actuated valve (10) includes an upper electromagnetic element (24) and a lower electromagnetic element (26) in a mirrored and facing relationship to each other. The electromagnetic elements (24, 26) define a central channel (20) that surrounds a vertical axis (22). The valve further includes an armature element (16) that is disposed intermediate the upper and lower electromagnetic elements (24, 26). The armature element (16) is pivotally mounted to an armature shaft (32). The armature shaft (32) is perpendicular to the vertical axis (22). The valve further includes a coil (14) disposed within the central channel (20) of each of the electromagnetic elements (24, 26).



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

HINGED ARMATURE ELECTROMAGNETICALLY ACTUATED VALVE

RELATED APPLICATION DATA

The present application is a continuation-in-part of commonly owned, co-pending application U.S. Serial No. 08/358,331, filed on November 9, 1994 for Hinged Armature Electromagnetically Actuated Valve, which is incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates generally to an electromagnetically actuated valve, and more particularly to an electromagnetically actuated valve having a pivoting armature.

BACKGROUND OF THE INVENTION

In the past, electromagnetic actuators and electromagnetically actuated valves included electromagnetic elements in facing relationship with each other having an armature element disposed intermediate the electromagnetic elements The electromagnetic elements and armature were disposed about a central vertical axis. The valve or actuator shaft extended collinear with the central vertical axis. The armature was attracted to either the upper or lower electromagnetic element and guided in its motion by an armature shaft. The armature shaft was also collinear with the central vertical axis. Therefore, the armature

displacement motion was parallel to the motion of the valve or actuator.

One problem with the known design arises when the valve is used in connection with an existing engine head. Because of the relatively small space available between the valve stems , it is difficult to use known electromagnetically actuated valves with an existing engine and still obtain the necessary magnetic pole face area. Therefore, it is desirable to have an electromagnetically actuated valve that is geometrically flexible and can be used with an existing engine head.

Another problem with the known electromagnetically actuated valve designs is that minor misalignment of the components created binding of the bearings and increased friction. Therefore, it is desirable to have an electromagnetically actuated valve that is robust and not as susceptible to minor misalignment of components.

Another problem with known electromagnetically actuated valves arises when it is desired to use lamination on the pole faces in order to reduce eddy currents. It is very difficult and expensive to use lamination on the known round or ring-shaped pole faces. Therefore, it is desirable to have an electromagnetically actuated valve having a pole face of a geometrical shape that is easily manufactured from laminations.

The natural frequency of the vibrational motion of unpowered electromagnetically actuated valves depends on the stiffness of springs used in the valve and the inertia of the moving components. A problem with the known electromagnetically actuated valves is that the inertia of the moving components is greater than desired. Therefore it is

desirable to have an electromagnetically actuated valve with reduced inertia of the moving parts, which results in smaller electromagnet weight and power.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to overcome one or more disadvantages and limitations of the prior art.

A significant object of the present invention is to provide an electromagnetically actuated valve that is easily retrofit to existing engine heads.

Another object of the present invention is to provide an electromagnetic actuator that requires reduced coil and electromagnet weight.

Another object of the present invention is to provide electromagnetic actuator that can be efficiently manufactured.

According to a broad aspect of the present invention, an electromagnetically actuated valve comprises an upper electromagnetic element and a lower electromagnetic element in a mirrored and facing relationship to each other. The electromagnetic elements define a central channel that surrounds a vertical axis. The valve further includes an armature element that is disposed intermediate the upper and lower electromagnets. The armature element is pivotally mounted to an armature shaft. The armature shaft is perpendicular to the vertical axis. The valve further includes a coil disposed within the central channel of each of the electromagnetic elements.

A feature of the present invention is that geometry of the valve is more flexible than prior known valves.

Another feature of the present invention is that the inertia of the moving components of the valve is decreased.

Another feature of the present invention is that the electromagnets and coils are easily manufactured.

These and other objects, advantages and features of the present invention will become readily apparent to those skilled in the art from a study of the following description of an exemplary preferred embodiment when read in conjunction with the attached drawing and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of an electromagnetically actuated valve of the present invention.

DESCRIPTION OF AN EXEMPLARY PREFERRED EMBODIMENT

Referring now to Figure 1, one embodiment of an electromagnetically actuated valve 10 of the present invention is shown in cross-section. In the embodiment shown, the valve 10 includes a pair of electromagnetic elements 12, a plurality of coils 14, and a core or armature element 16. Each of the electromagnetic elements 12 has a pole face 18 with a central channel 20 disposed in the face 18. The central channel 20 surrounds a central vertical axis 22. The coil 14 of each electromagnetic element is disposed within the channel 18.

In the embodiment shown in Figure 1, the pair of electromagnetic elements 12 further comprises an upper electromagnetic element 24 and a lower electromagnetic element 26. The upper and lower electromagnetic elements are in a mirrored relationship to each other, with the faces 18 and central channels 20 of the upper and lower electromagnetic elements being in a facing relationship to each other.

Disposed intermediate the upper and lower electromagnetic elements 24, 26 is the armature element 16. The armature element 16 provides an upper pole face 28 and a lower pole face 30. The armature element is rotatingly or pivotally mounted to an armature shaft 32, such that the armature shaft operates similar to a hinge. The armature element 16 defines a proximal end 34 adjacent the armature shaft 32 and a distal end 36 distal from the armature shaft 32. The armature is shaped so as to taper in thickness from the proximal end 34 down to the distal end 36.

The valve 10 further includes a valve shaft 38 that extends in axial alignment with the central vertical axis 22 of the valve. The electromagnet elements 24, 26 are moveably engaged around the valve shaft 38 and the armature 16 is interconnected to the valve shaft 38. More specifically, in the embodiment shown in Figure 1, a plurality of bearings 40 are disposed intermediate the valve shaft 38 and the electromagnet elements 24, 26 to allow sliding motion of the valve shaft 38. Therefore, the valve shaft 38 moves in a direction parallel with the vertical axis 22 of the valve.

As previously described, the armature 16 rotates or pivots about the armature shaft 32. The armature shaft 32 extends perpendicular to the valve shaft 38 and the vertical

axis 22. Also, the armature shaft 32 is offset from the valve shaft 38. Therefore, the armature 16 pivots in an upward and downward direction, however, the armature's direction of movement is at an angle and is not parallel to the direction of movement of the valve shaft 38. Moreover, the armature's direction of movement is not parallel to the vertical axis 22 of the valve.

There are several advantages of the pivoting armature design of the present invention. First, the pivoting armature allows for a low profile and flexible geometry. As a result, it is easier to retrofit existing engines and other applications with the valve 10. Another advantage of the pivoting armature is that the armature is less susceptible to minor misalignment of the components. Minor misalignment could cause increased friction and binding of the bearings. A third advantage is that the air gaps traversed by the magnetic flux in the valve are smaller than in a conventional design. Therefore, magnetic flux leakage is minimized and coil weight and coil waste power are reduced. A fourth advantage is that the inertia of the moving components is reduced by the use of the pivoting armature as compared to an axially moving armature. The natural frequency of the vibrational motion of the valve is dependent upon the inertia of the moving components. The reduced inertia therefore results in smaller electromagnet weight.

The electromagnet elements 24, 26 and the coils 14 are preferably rectangular in cross-section. As a result, the pole faces 18 of the electromagnets are also rectangular shaped in cross-section. The pole faces 18 of the electromagnet elements may be easily modified to accommodate the shape of the armature 16, as desired for each application.

An advantage of the rectangular-shaped electromagnet elements 24, 26 and coils 14 is evident when attempting to retrofit an existing engine with an electromagnetically actuated valve. In existing engines, the distance between valve stems is relatively small. The rectangular shape of the pole faces of the present invention allows greater flexibility of design and may allow the pole face area to double within the geometric envelope allowed by the existing engine. Another advantage of the rectangular shapes of the electromagnet elements is that the electromagnets are easily laminated in order to reduce eddy currents. More specifically, the rectangular shaped electromagnetic elements may be easily manufactured from silicon steel laminations. Still another advantage is that the excess mass in the magnetic return paths, typically found in round or ring-like pole faces, is minimized by the rectangular shape of the electromagnet elements.

The valve 10 further includes a plurality of springs 42. The springs 42 are interconnected to the armature 16 through the valve shaft 38. The springs 42 serve to return the armature 16 to a central position after actuation of the valve. The springs 42 are preferably made from wire bent into a helix of variable pitch and radius. Therefore, the springs are non-linear because the force produced as the springs are compressed is not proportional to the distance of compression. Instead, the springs have an increasing stiffness constant as the compression is increased. As compared to linear springs, the non-linear springs of the present invention produce armature movement having a shorter period. Therefore, the motion from one end to the other takes less time, which is critical for the use of valves that run at higher rates of revolution, for example in engines.

Another advantage of the use of non-linear springs 42 is that the spring forces have a force versus displacement profile that resembles and tracks the magnetic forces produced by the electromagnets 24, 26. More specifically, the forces produced by the electromagnets do not vary linearly with the distance of the electromagnets from the armature 16. Instead, the electromagnets produce forces that are proportionally much stronger when the distance of the armature from the electromagnets is very small The combination of the non-linear springs and the electromagnets allows the electromagnetic force to be able to overcome the spring force at any distance, while using smaller currents.

There has been described hereinabove an exemplary preferred embodiment of the electromagnetically actuated valve according to the principles of the present invention. Those skilled in the art may now make numerous uses of, and departures from, the above-described embodiments without departing from the inventive concepts disclosed herein. Accordingly, the present invention is to be defined solely by the scope of the following claims.

THE CLAIMS

I claim as my invention:

1. An electromagnetically actuated valve comprising:

an upper electromagnetic element and a lower electromagnetic element, each of said electromagnetic elements defining a central channel, said central channel surrounding a vertical axis, and further wherein said upper and lower electromagnetic elements are in a mirrored and facing relationship to each other;

an armature element disposed intermediate said upper and lower electromagnets, said armature element being pivotally mounted to an armature shaft, said armature shaft being perpendicular to said vertical axis; and

a coil disposed within the central channel of each of said electromagnetic elements.

2. An electromagnetically actuated valve in accordance with Claim 1 further comprising a valve shaft about which the electromagnets and coils are disposed, said valve shaft being aligned with said vertical axis.

3. An electromagnetically actuated valve in accordance with Claim 1 wherein said electromagnets have a rectangular cross-section.

4. An electromagnetically actuated valve in accordance with Claim 1 wherein said coil has a rectangular cross-section.

5. An electromagnetically actuated valve in accordance with Claim 1 further comprising at least one spring interconnected to said valve shaft, said spring serving to return said armature to a central position.

6. An electromagnetically actuated valve in accordance with Claim 5 wherein said spring is non-linear.

7. An electromagnetically actuated valve in accordance with Claim 2 wherein said valve shaft and said armature shaft are offset from each other.

8. An electromagnetically actuated valve in accordance with Claim 1 wherein said armature comprises a first end adjacent said armature shaft and a second end distal said armature shaft and further wherein said armature is tapered in shape from said first end to said second end.

9. An electromagnetically actuated valve comprising:

an upper electromagnetic element and a lower electromagnetic element, each of said elements defining a central channel, said central channel surrounding a vertical axis, wherein said upper and lower electromagnetic elements are in a mirrored and facing relationship to each other;

an armature element disposed intermediate said upper and lower electromagnets, said armature element being rotatingly mounted to an armature shaft such that said armature rotates about said armature shaft in a non-parallel direction to said vertical axis; and

a coil disposed within the central channel of each of said electromagnetic elements.

10. An electromagnetically actuated valve in accordance with Claim 9 further comprising a valve shaft about which the electromagnets and coils are disposed, said valve shaft being aligned with said vertical axis.

11. An electromagnetically actuated valve in accordance with Claim 9 wherein said electromagnets have a rectangular cross-section.

12. An electromagnetically actuated valve in accordance with Claim 9 wherein said coil has a rectangular cross-section.

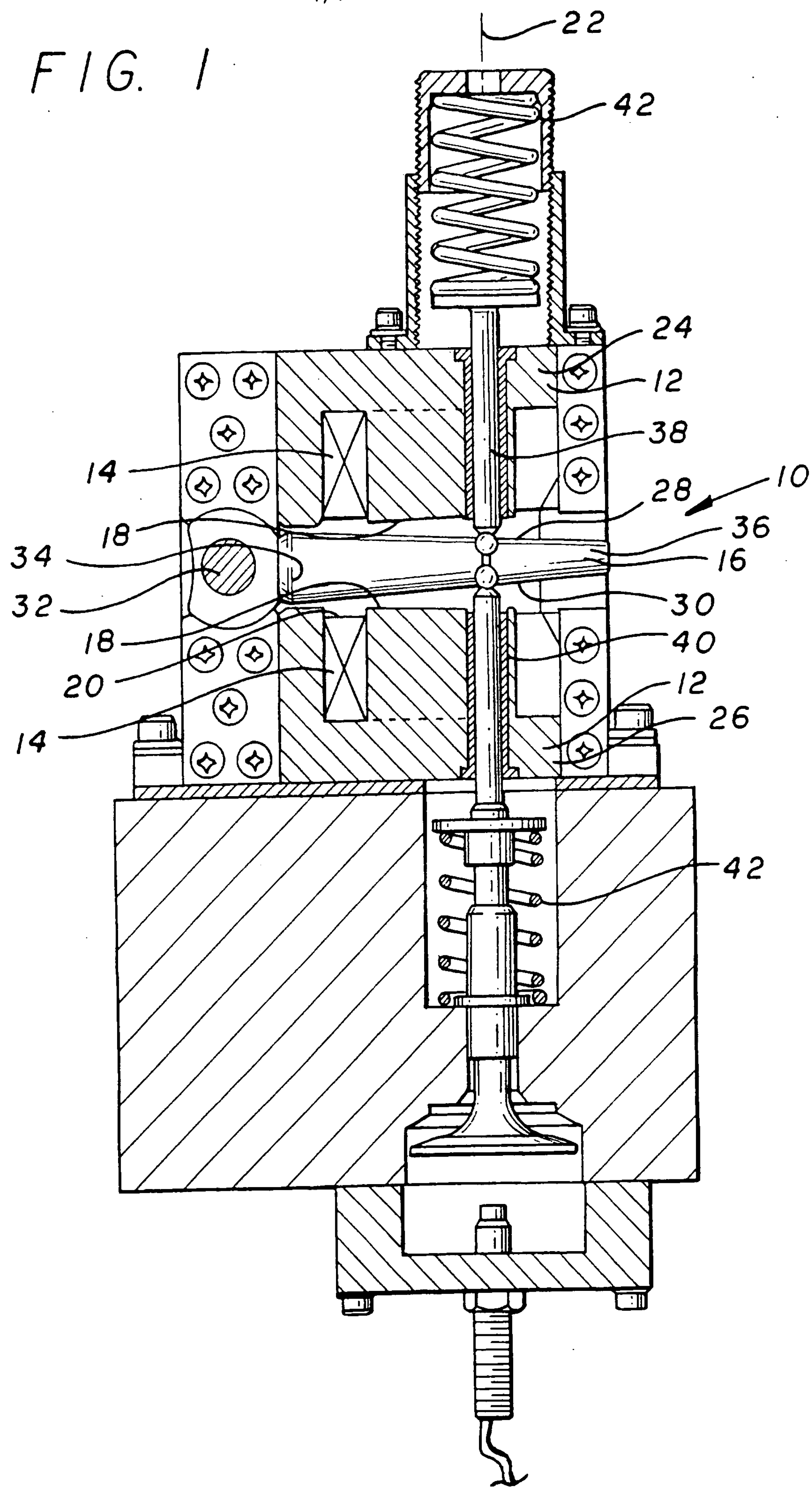
13. An electromagnetically actuated valve in accordance with Claim 9 further comprising at least one spring interconnected to said armature, said spring serving to return said armature to a central position.

14. An electromagnetically actuated valve in accordance with Claim 13 wherein said spring is non-linear.

15. An electromagnetically actuated valve in accordance with Claim 10 wherein said valve shaft and said armature shaft are offset from each other.

16. An electromagnetically actuated valve in accordance with Claim 9 wherein said armature comprises a proximal end adjacent said armature shaft and a distal end distal said armature shaft and further wherein said armature is tapered in shape from said proximal end to said distal end.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/14827

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F16K 31/02
US CL : 251/129.09, 129.2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 251/129.09, 129.2, 129.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,783,047 (BALTUS ET AL) 08 November 1988, fig. 1 and col. 3, lines 22-35.	1-4, 9-12
A	FR, A, 1,233,442 (PICAT) 12 OCTOBER 1960	1-16
A	US, A, 1,767,058 (EISEMAN) 24 June 1930	1-16
A	US, A, 3,244,397 (FATTOR) 05 April 1966	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 MARCH 1996	09 APR 1996

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	JOHN RIVELL
Facsimile No. (703) 305-3230	Telephone No. (703) 308-2599